Stress ecology and ecological risk assessment

Application of computational modelling for assessing the ecological risk of chemical and non-chemical stressors

Nico M. van Straalen

Ecological risk assessment must deal with the complexity of ecosystems

Two approaches in ecological risk assessment

1. Start in the lab, extrapolate to the field

2. Assess the field directly

Two approaches in ecological risk assessment

- Start in the lab, extrapolate to the field
  - Follows the paradigms of human toxicology
  - Indicator species cultured in the laboratory
  - Test protocol development, harmonization of methods
  - Models for dose-response analysis
  - Species sensitivity distributions
  - Applicable to new substances
- Assess the field directly
  - Ecology and environmental chemistry become crucial
  - Validation of the substance-specific laboratory approach
  - More suitable for existing substances

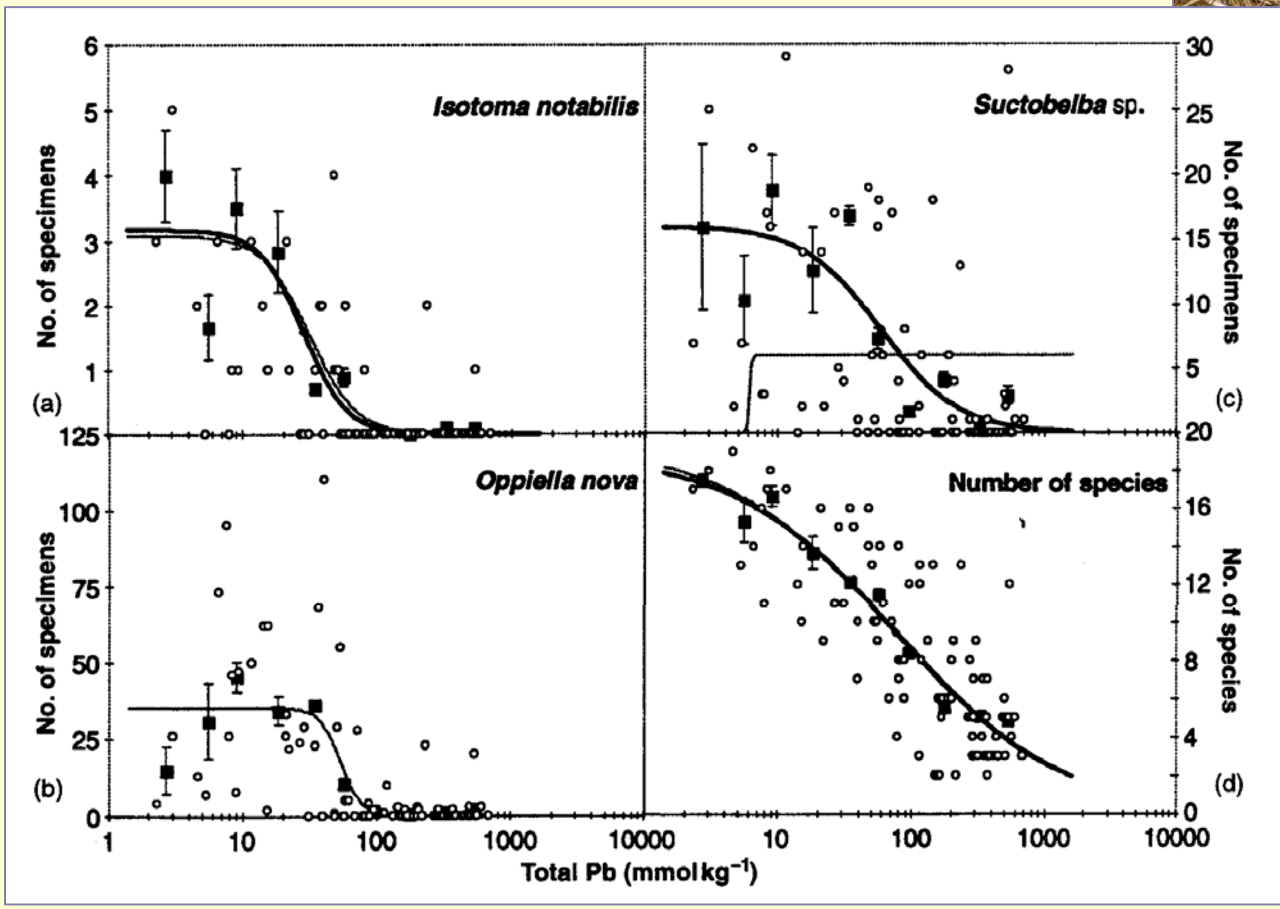
Ecological risk assessment in the field

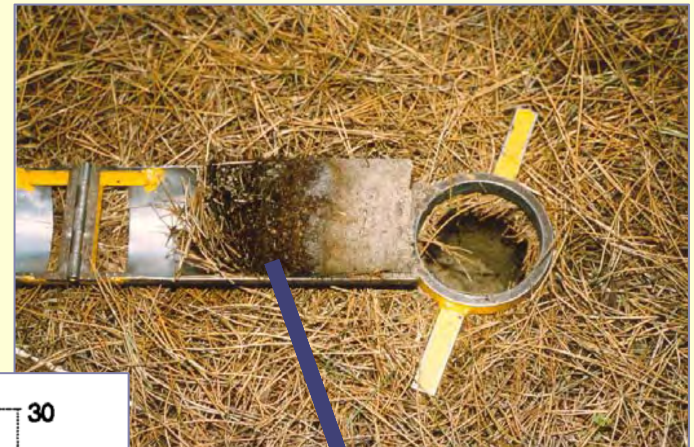
- Find a pollution gradient around a point source
- Measure ecological variables at various distances from the source

- Use regression-type techniques to estimate risks and safe exposure levels

Gradient studies follow the regression approach

Van Straalen & Løkke (1997) Ecological Risk Assessment of Contaminants in Soil. Chapman & Hall

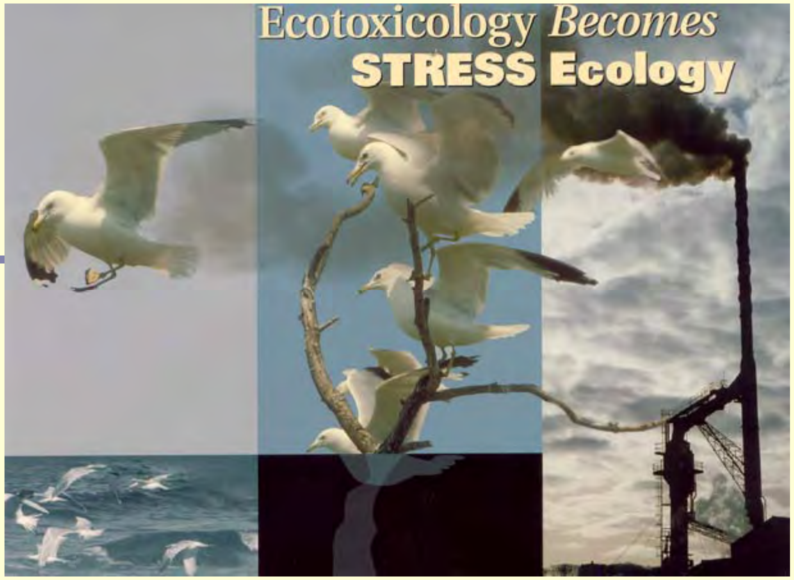




Characteristics of diffuse pollution

- Absence of gradients
- Absence of good reference sites
- Low to moderate concentrations of chemicals
- Absence of ecological disasters
- Large spatial heterogeneity
- Mixtures of chemicals from different sources
- Legacies from the past

The framework of stress ecology



- Environmental concentrations of many chemicals are decreasing
- Other determinants of ecosystem function come to interact with anthropogenic chemicals
- Natural fluctuations, spatial heterogeneity, *etc.* become important
- Chemical threats must be viewed as part of ecological stress

Van Straalen, N.M. (2003) Environ Sci Technol 37(17): 324A-330A

Introducing four case studies

- Grassland soils polluted by historical municipal waste disposal
  - Invertebrates
  - Microbial communities
- Polluted floodplain soil in a freshwater river estuary
- Polluted sediments in harbours and canals in a salinity gradient

NWO
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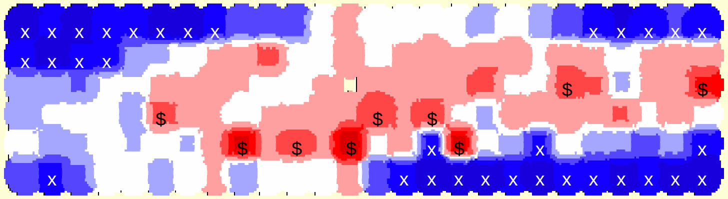
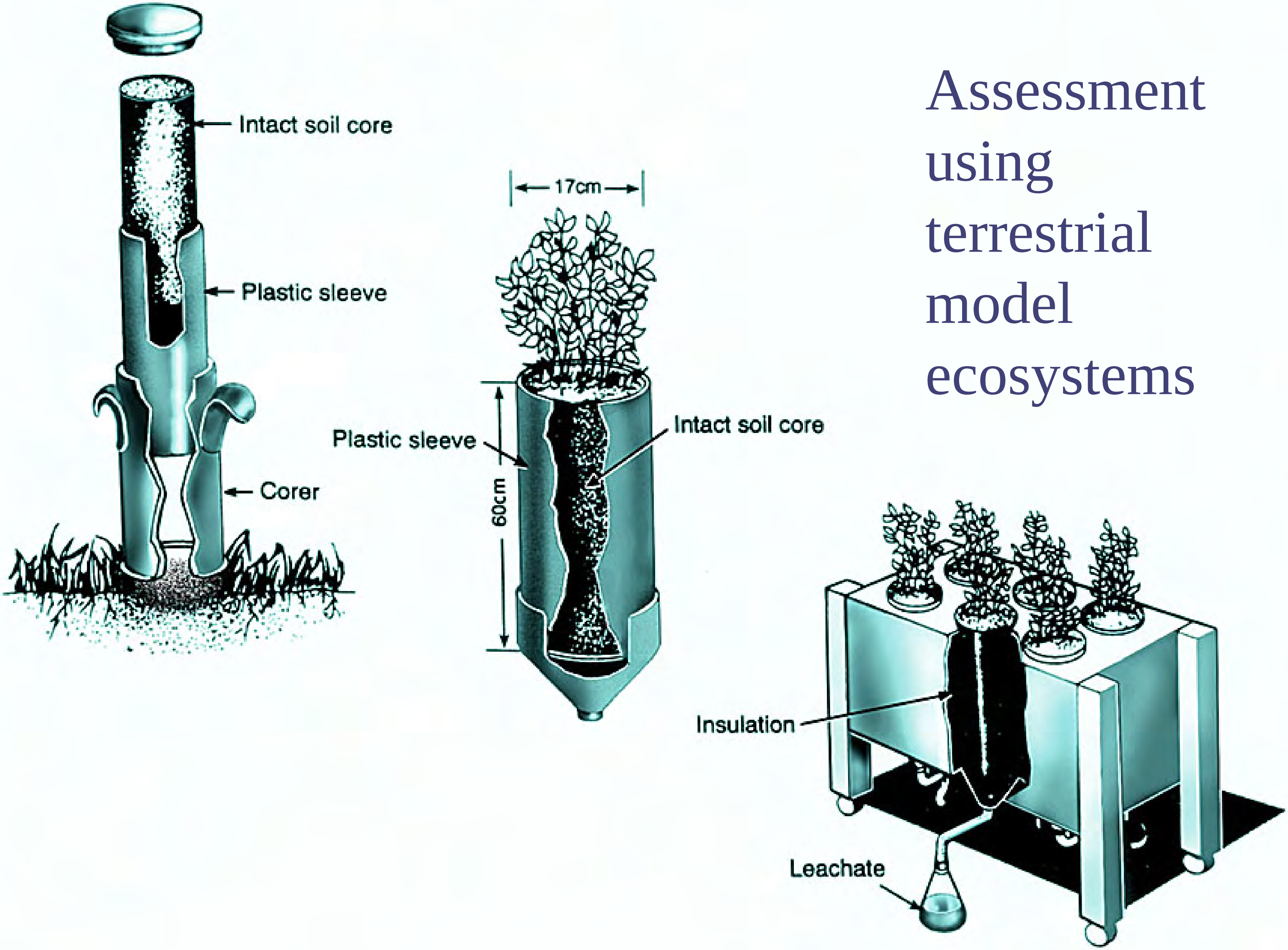
The SSEO programme: System-oriented Ecotoxicological Research

Pb, Cu, Zn, Cd, PAH

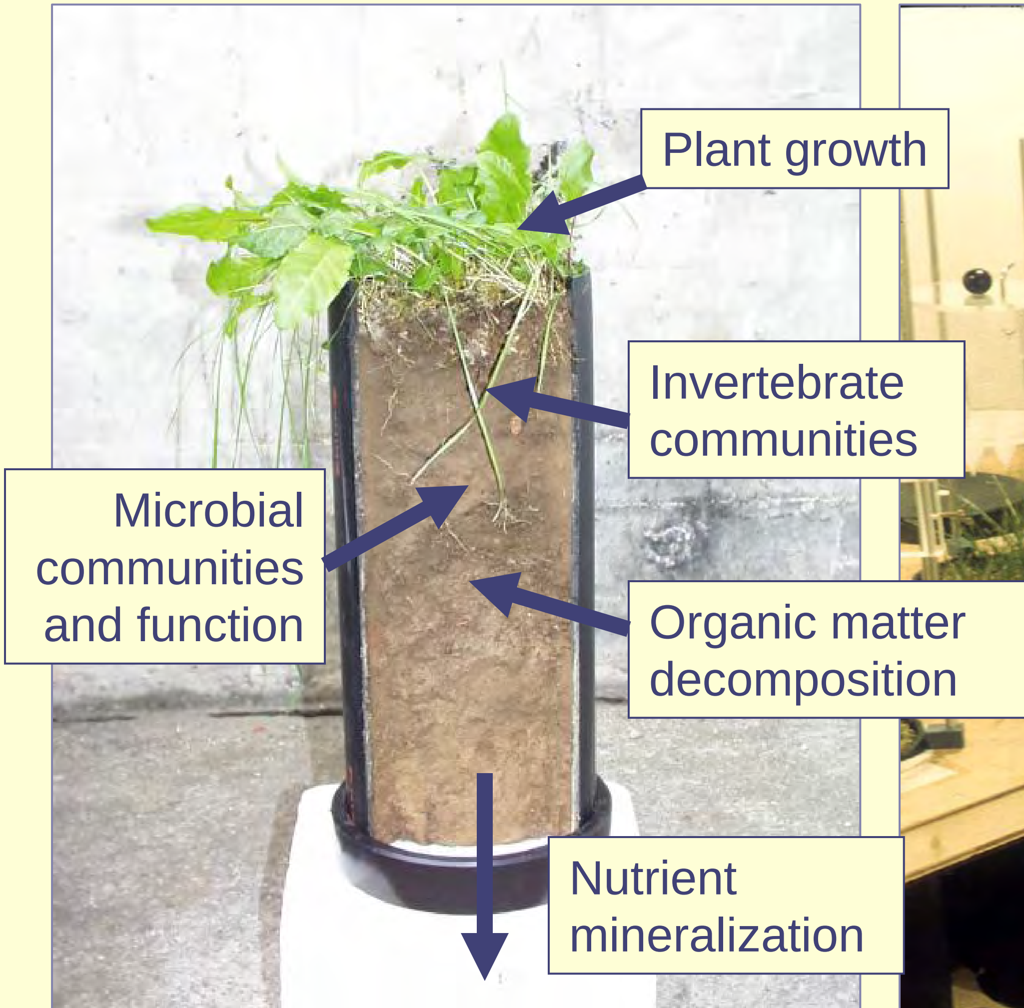


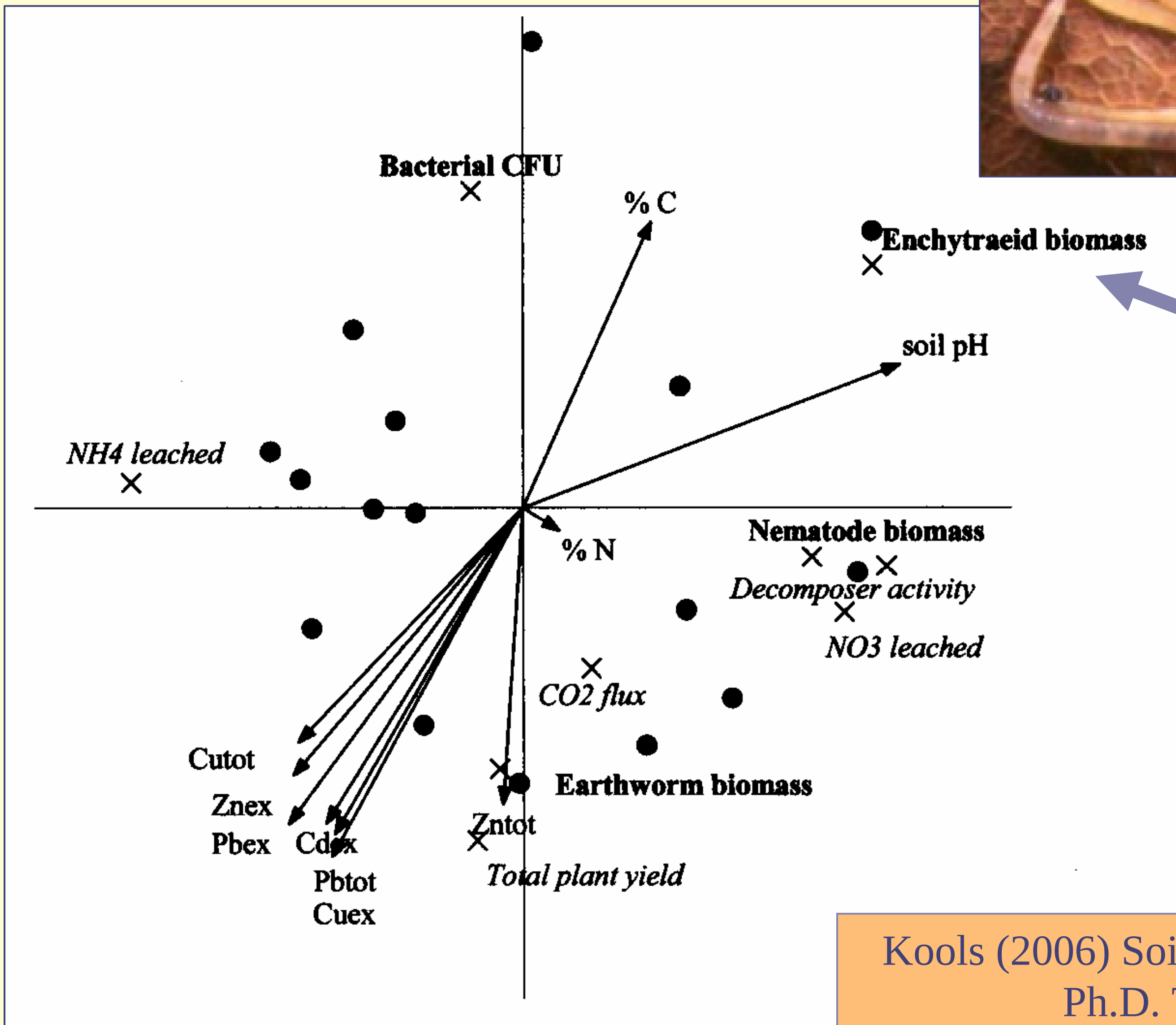
History of land improvement by disposal of municipal waste

Assessment using terrestrial model ecosystems




HENK KOOYMAN BV

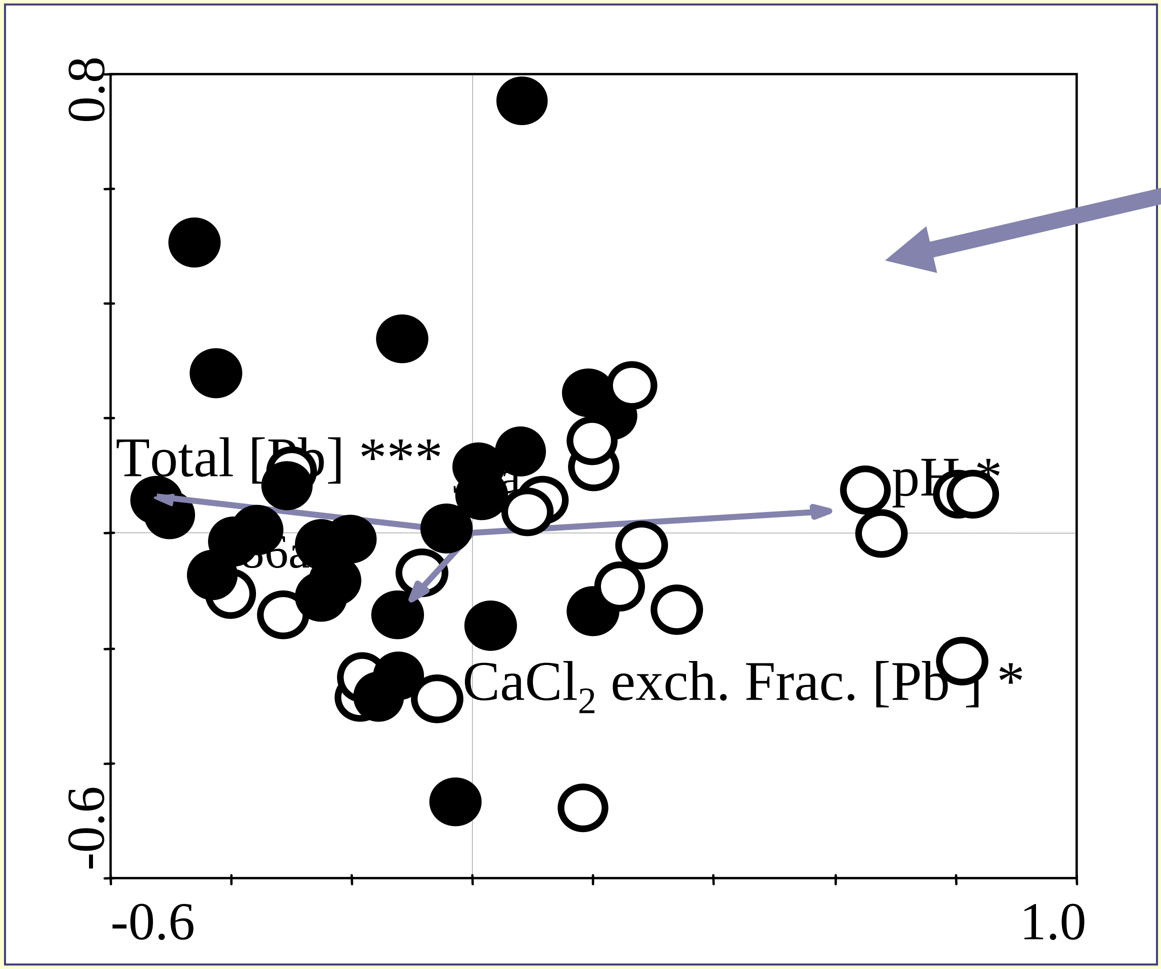

Plant growth
Invertebrate communities
Microbial communities and function
Organic matter decomposition
Nutrient mineralization



Negative association between biomass of enchytraeid worms and heavy metal concentrations

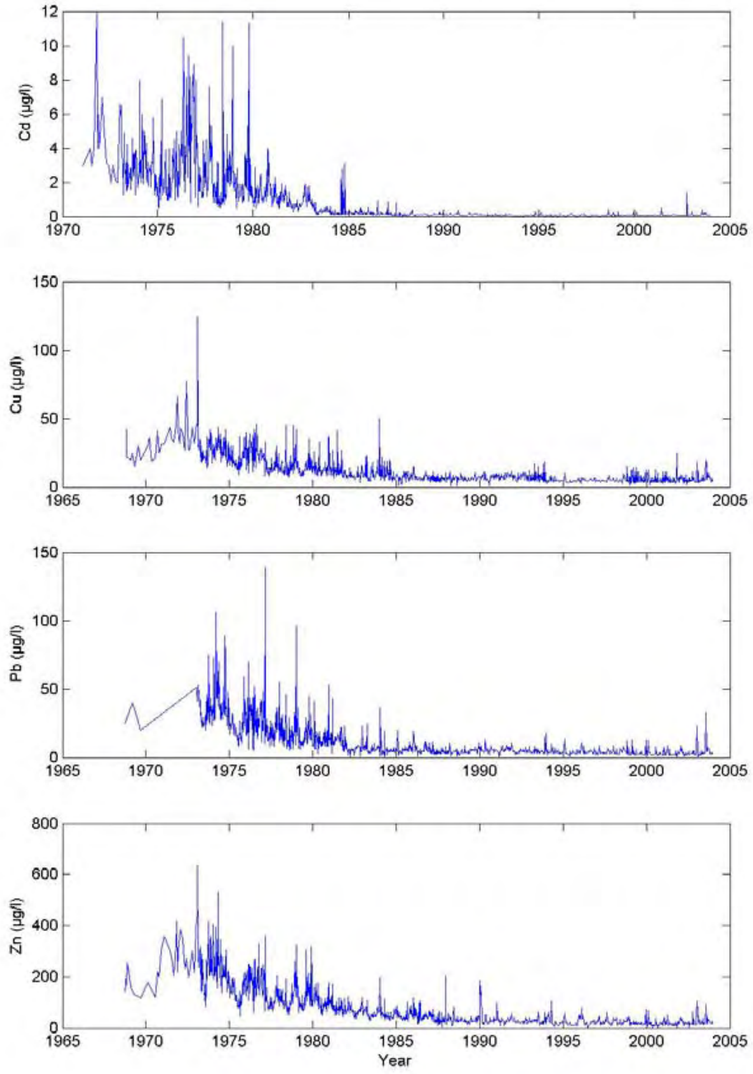
Kools (2006) Soil Ecosystem Toxicology. Ph.D. Thesis, Vrije Universiteit

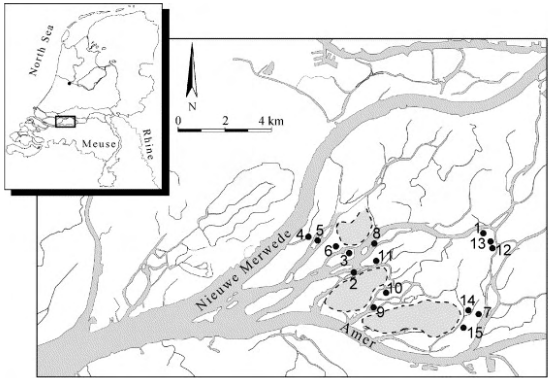
Microbial physiological profiles measured using Eco-plates (Biolog Inc.)



Negative association between physiological profiles of microbial communities and soil lead

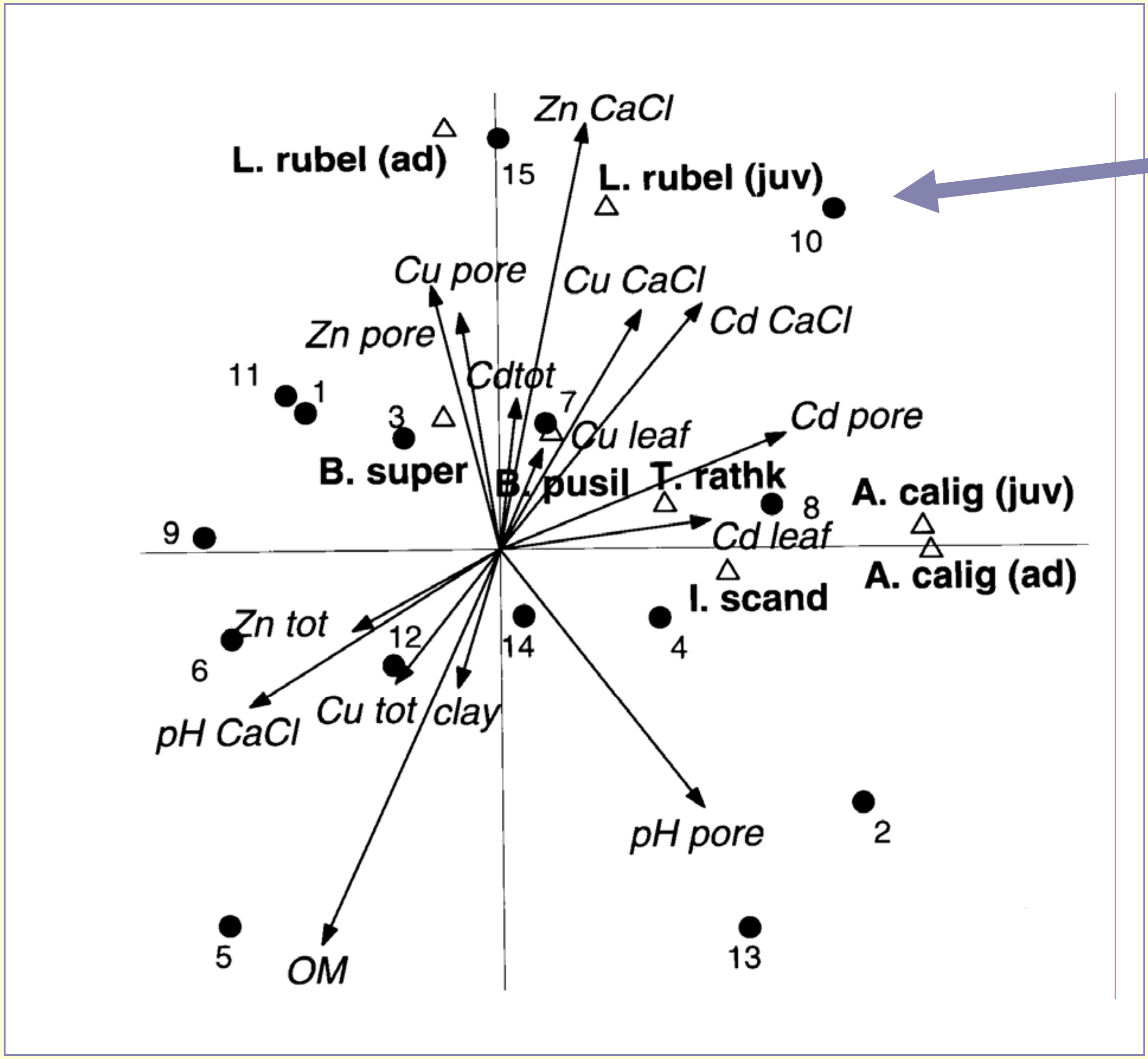
Boivin *et al.* (2006) Appl. Soil. Ecol. 34: 103-113





"Biesbosch"

History of deposition of contaminated sediment from the rivers Rhine and Meuse

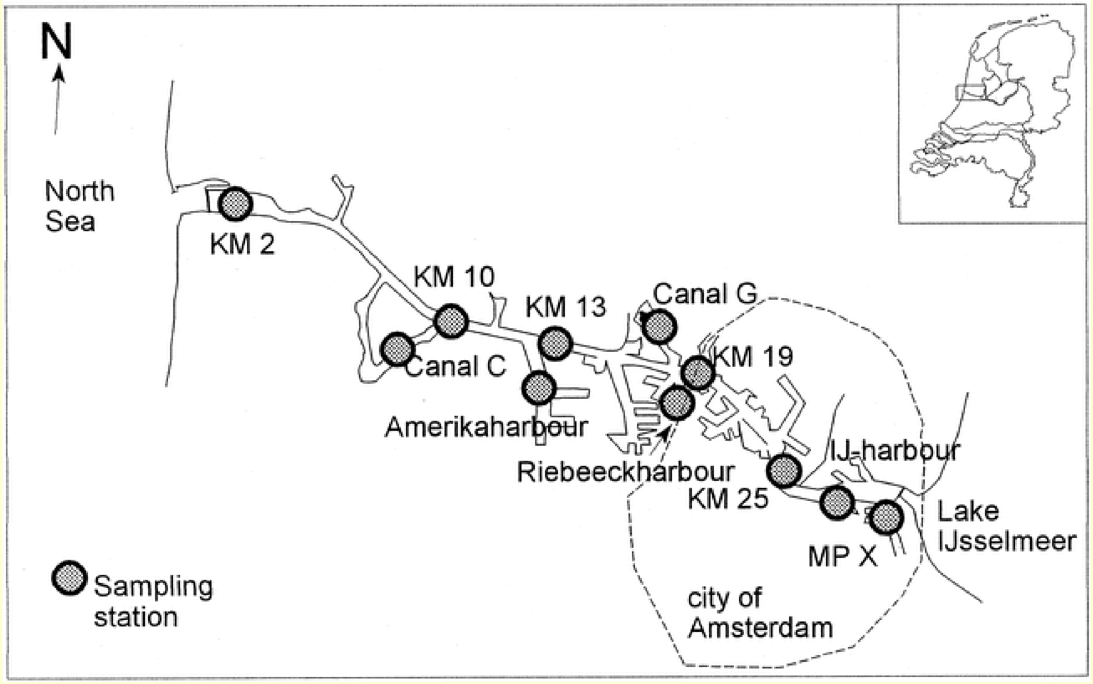


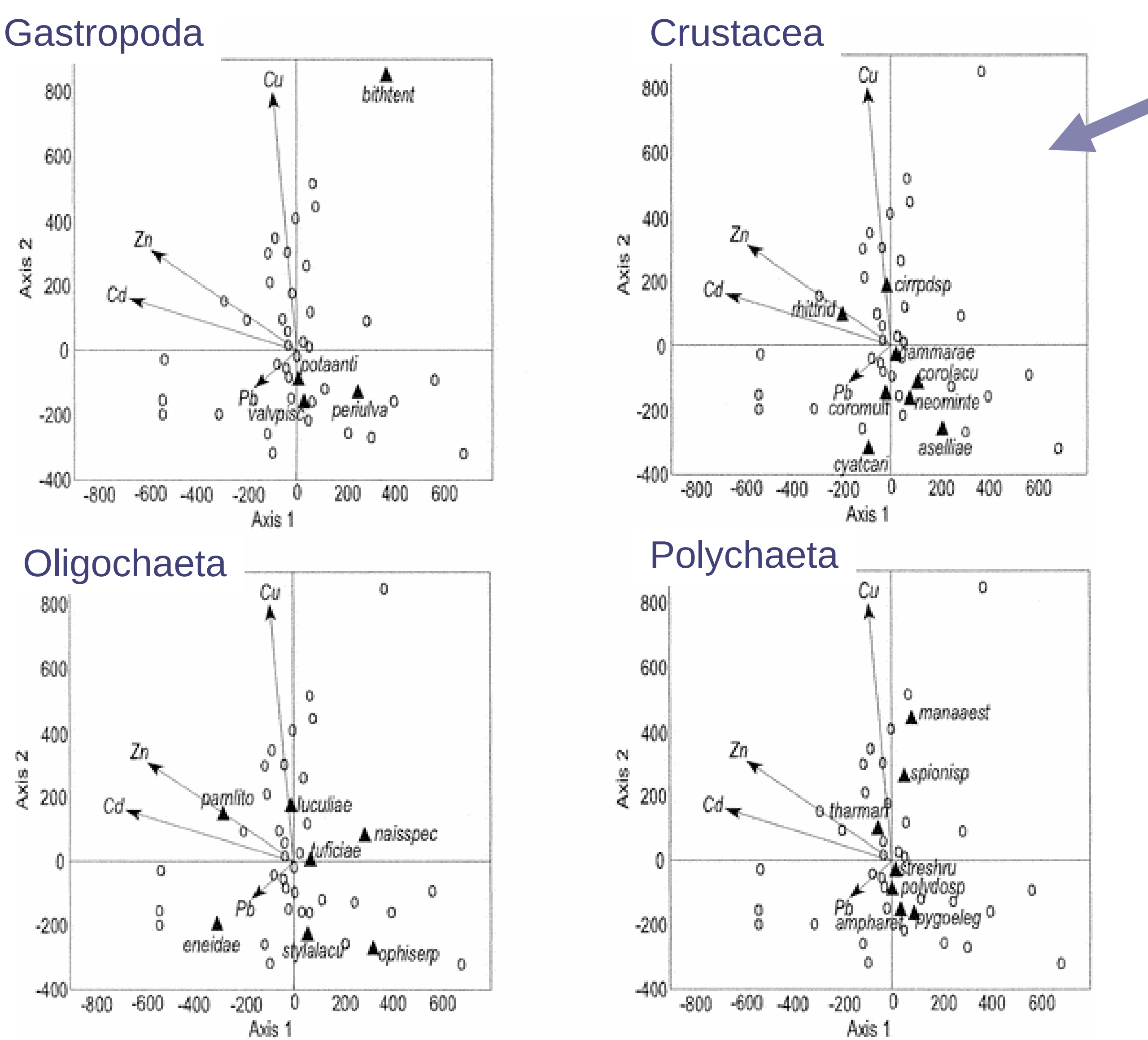
Hobbelen *et al.* (2006) Soil Biol Biochem 38: 1596-1607

Positive association between earthworm biomass and exchangeable zinc

No clear negative effects of heavy metals, despite high total concentrations

Contaminated sediments of the North Sea canal (harbours of Amsterdam)





Negative association between benthic crustaceans and sediment copper

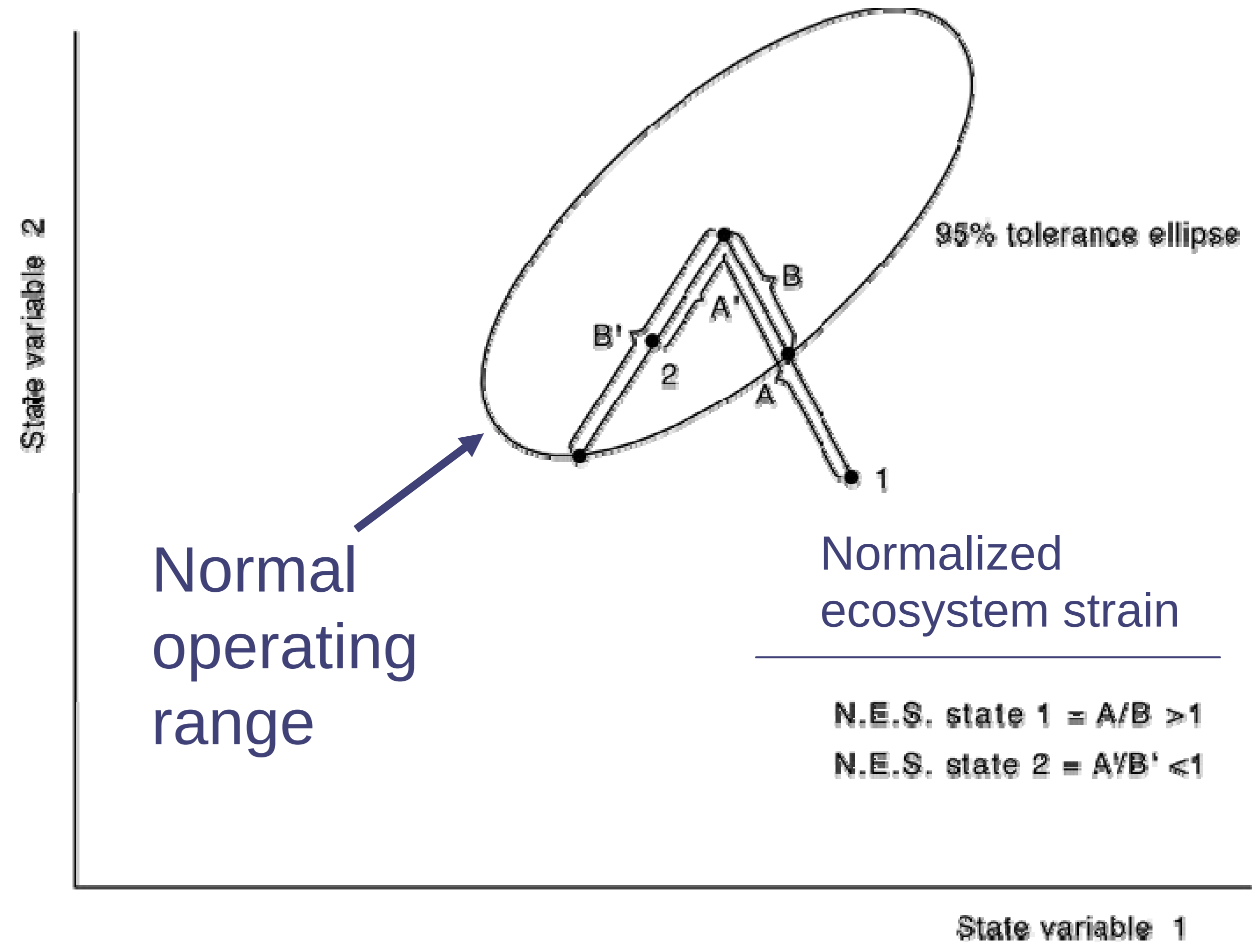
Variance partitioning: 45% ecological factors, 8.6% trace metals

Peeters, E.T.H.M. *et al.* (2000) Env Tox Chem 19: 1002-1010

A multidimensional stress ecology approach to ecological risk assessment

- Effects of contaminants are superimposed upon natural variability and ecological factors
- Ecological factors must be measured alongside aspects of contamination
- Effects of contaminants can be filtered out of natural variation using sensitive multivariate statistical techniques
- Include as many ecological variables as possible, structural, functional, microbial, faunal, etc. aspects
- Define the baseline (normal operating range) of the system from fluctuations in ecological variables under unstressed conditions
- Evaluate ecological risk as a deviation from the (multivariate) normal operating range

Risk is deviation from NOR



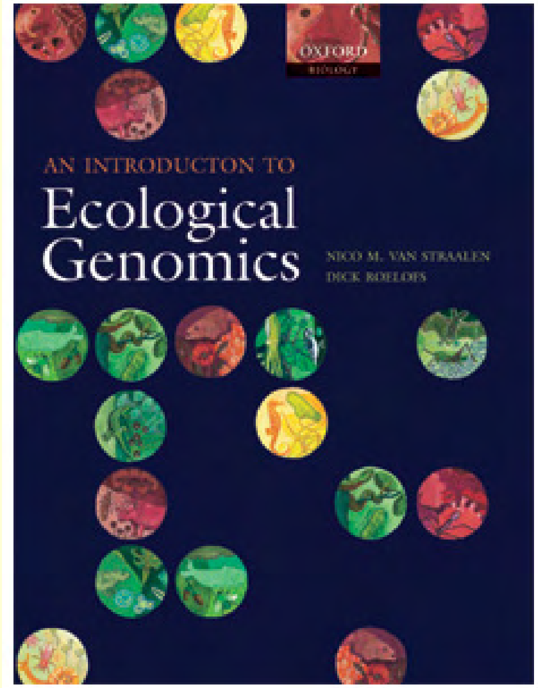
Normal operating range

Normalized ecosystem strain

Odum, E.P. *et al.* (1979) Biosci 29: 349-352. Kersting, K. (1984) Ecol Bull 36: 150-153.

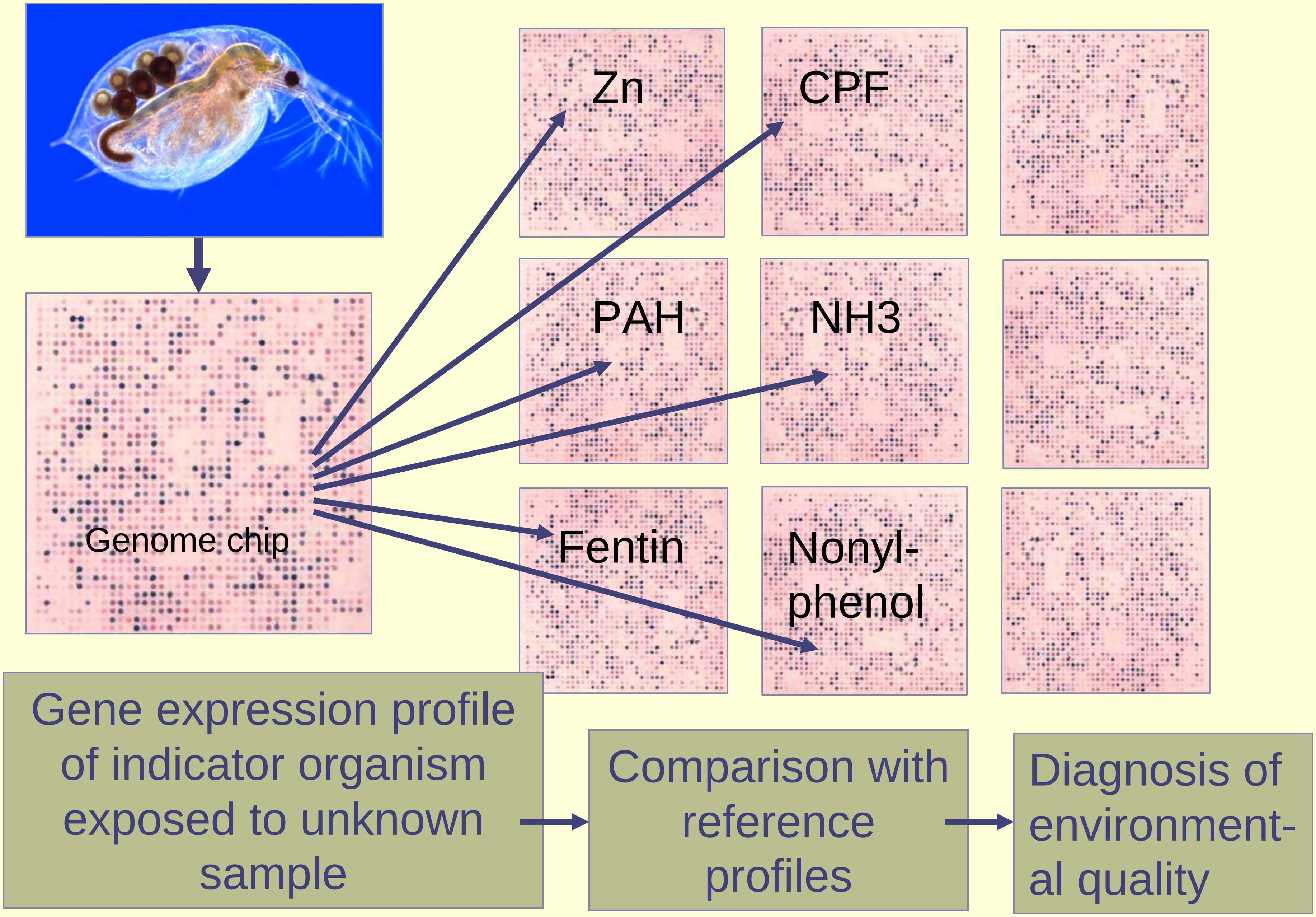
The new science of ecological genomics

“A scientific discipline that studies the structure and functioning of a genome with the aim of understanding the relationship between the organism and its biotic and abiotic environment”



Van Straalen, N.M. & Roelofs, D. (2006) An Introduction to Ecological Genomics. Oxford University Press

- Genome
  - Genes
    - rRNA, tRNA, snRNA
    - mRNA → Proteins
  - Pseudogenes
  - Non-coding DNA
    - Regulating sequences
    - Repetitive DNA
    - Transposons

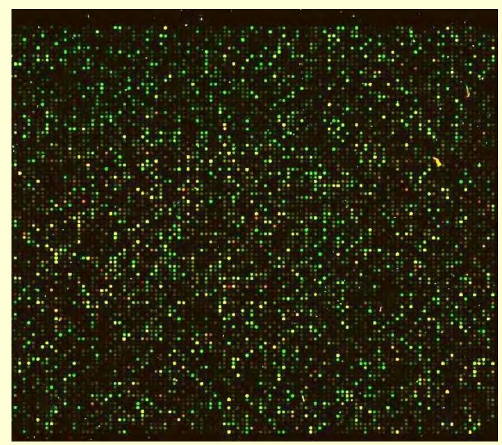

Zn
CPF
PAH
NH3
Genome chip
Fentin
Nonyl-
phenol
Gene expression profile of indicator organism exposed to unknown sample
Comparison with reference profiles
Diagnosis of environment-al quality

Is it polluted?

Expose indicator species to soil sample

www.Collembase.org

Develop gene expression profile



Match expression profile with reference, look at indicator genes

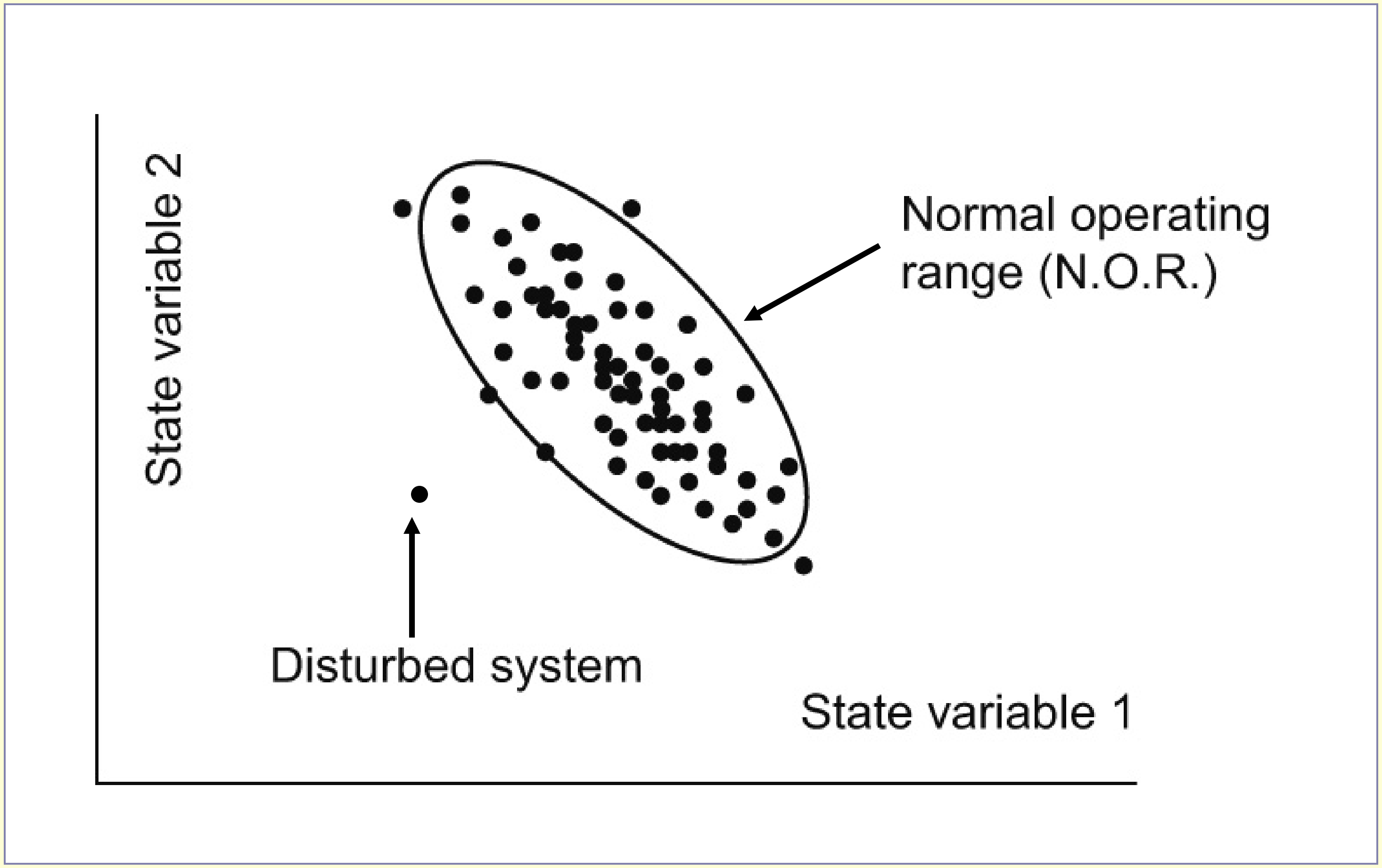
- Soil certification
- Diagnosis of pollution
- Bioavailability assessment

Ecotoxicogenomics in ecological risk assessment

Ankley *et al*. (2006)
Env Sci Technol 40:
4055-4065

- Ecotoxicogenomic data are highly multidimensional
- Resolution, substance-specificity and rapidity seem to be significant advantages
- Gene expression profile is a direct reflection of toxicity pathways and modes of action
- The same multivariate statistics are applied to transcriptomic data and ecological stress analysis
- Still many practical and conceptual challenges need to be overcome before transcriptomics will be accepted in risk assessment

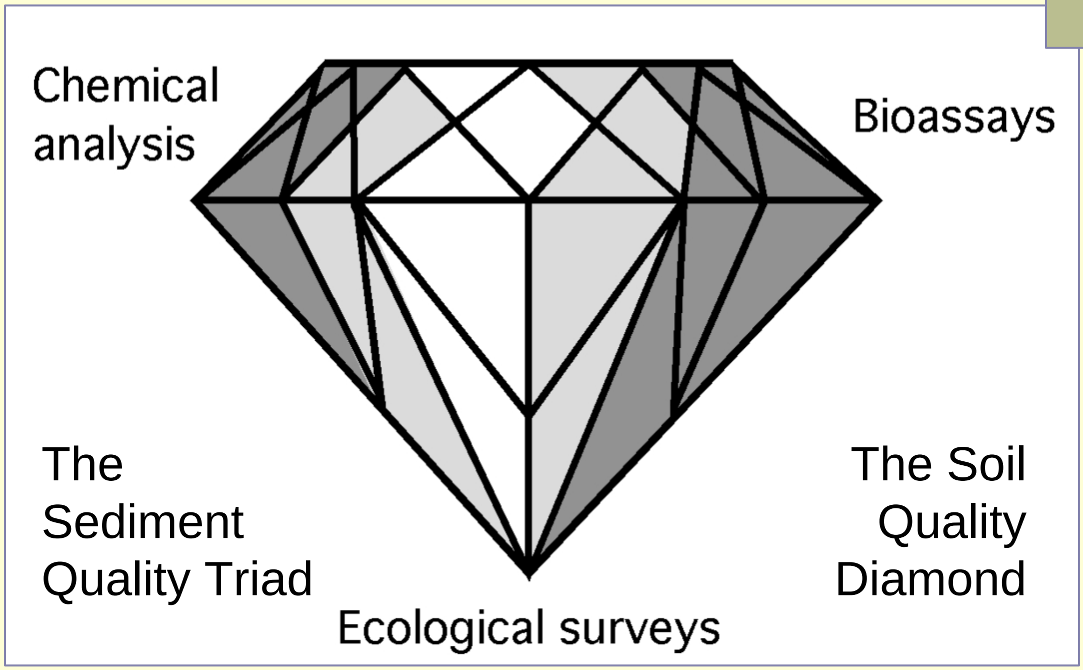
Normal operating range: a framework for interpreting gene expression profiles?



From SQT (SQD) to weight of evidence: in line with the stress ecology framework

Burton, G.A. *et al.* (2002) Human Ecol Risk Assessm 8: 1675-1696

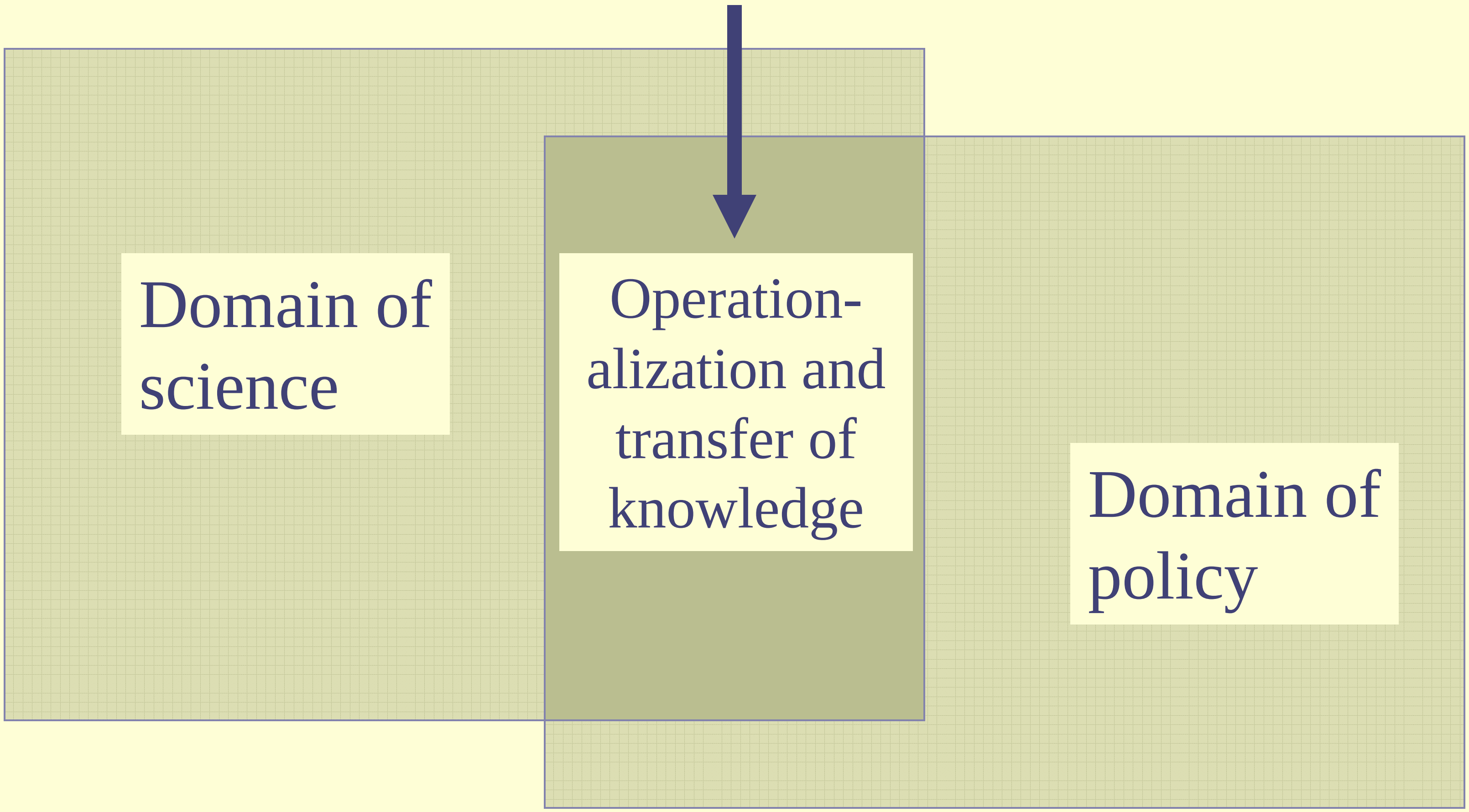
Three lines of evidence



Weight-of-evidence framework

Multiple lines of evidence taken into account

Indicators can act as boundary objects



Turnhout, E. (2003) Ph.D. Thesis, Vrije Universiteit, Amsterdam
Gieryn, T.F. (1983) Am Soc Rev 48: 781-795

Computational needs of stress ecology

- Filter effects of contaminants from the effects of many natural, biotic and abiotic, stress factors
- Estimate variance components attributable to different sources
- Develop methods to characterize the normal operating range and deviations from it
- Develop an asssessment scheme to value effects of toxicants exceeding or not exceeding the range of natural variation

Acknowledgements

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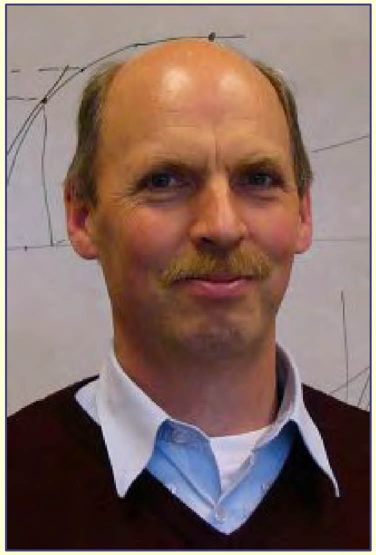

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